4th NOAA Testbeds and Proving Grounds Committee Meeting:

NOAA's Contribution to the

U.S. Joint Center for Satellite Data Assimilation (JCSDA)

S.-A. Boukabara, L.-P. Riishojgaard and J. Yoe
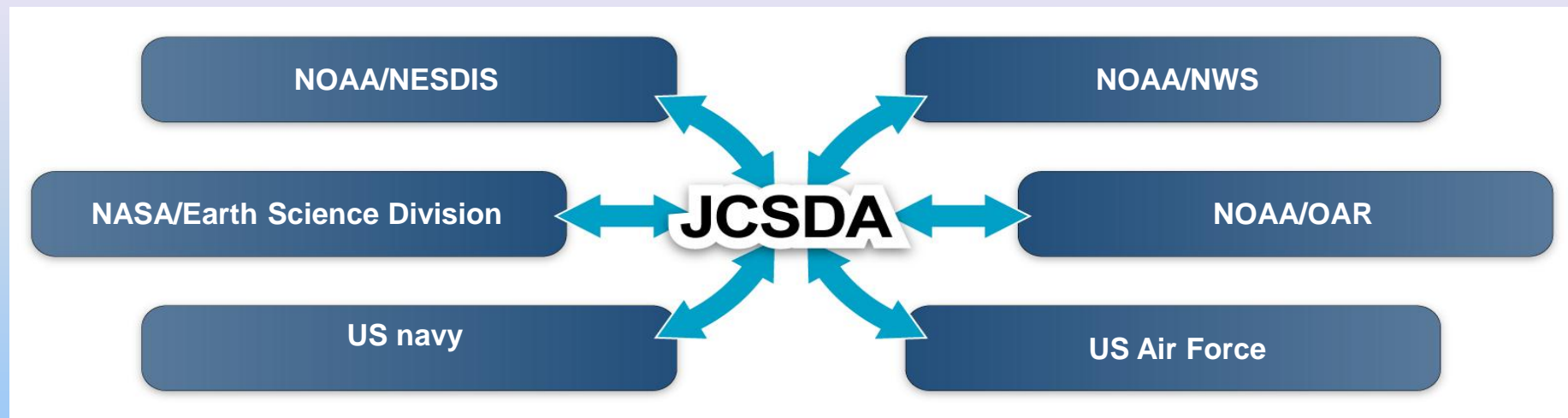
NCWCP/College Park, MD, April, 2013

Outline

Introduction

❖ **JCSDA started as a NASA/NOAA collaboration initiated in 2000**

❖ **Objective: Increase forecast accuracy;**

❖ **Approach: Gathering and leveraging of expertise in:**

- Modeling
- Computing
- Observational data

❖ **Inclusion of DoD (Navy and AFWA)**

❖ **Memorandum of Agreement signed May 2008**

❖ **Terms of reference signed in August 2008**

JCSDA Partners, Vision, Mission

NOAA/NESDIS **NOAA/NWS**

NASA/Earth Science Division **JCSDA** **NOAA/OAR**

US navy **US Air Force**

Vision:

An interagency partnership working to become a world leader in applying satellite data and research to operational goals in environmental analysis and prediction

Mission:

…to accelerate and improve the quantitative use of research and operational satellite data in weather, ocean, climate and environmental analysis and prediction models.

JCSDA Management

Agency Executives

NASA, NOAA, Department of the Navy, and Department of the Air Force

Management Oversight Board

NOAA / NWS / NCEP (Higgins)

NASA/GSFC/ESD (Dr Hildebrand)

NOAA / NESDIS / STAR (A. Powell)

NOAA / OAR (Atlas)

Air Force Director of Weather (Col. Edwards)

Navy / N84 and NRL (Chang, Curry)

Advisory Panel

JCSDA Executive Team

Director (Riishojgaard)

Deputy Director (Boukabara)

Partner Associate Directors

(Lapenta, Benjamin, Rienecker, Phoebus, Zapotocny)

Science Steering Committee

JCSDA Mode of operation

- **JCSDA partner's in-Kind Research**
    - Research undertaken independently by partners, overlapping with JCSDA priorities
    - Results/deliverables made available and shared with/between partners

- **Directed research (short-term return-on-investment expected)**
    - Carried out by the partners
    - Mixture of new and leveraged funding

- **External research (near-term return-on-investment expected)**
    - Grants awarded following proposals submitted (administered alternately by NOAA, NASA with contribution from DoD, on behalf on JCSDA)
    - Open to the broader research community
    - Funding awarded competitively, peer review process

- **Visiting scientist program (see www.jcsda.noaa.gov)**
    - Great way to initiate or strengthen involvement with the Joint Center
    - Wide-open to data assimilation scientists from everywhere
    - Short-term (a few weeks/months) and Long-term (a few years) VS
        - Identify host at JCSDA partner institution; work on JCSDA-relevant topic

Internal Research Program

- This is research for internal partners scientists, funded by JCSDA-labeled budgets

- Within NOAA, this effort is traditionally coordinated with other programs –GOESR, JPSS- (success story with JPSS program for funding NPP-related impact assessment study and accelerated R2O)

- This is the mechanism for immediate R2O (as opposed to longer-term R2O with the external research program)

- In NOAA, examples include:
  - Assimilation of a new sensor directly into a JCSDA partner model
  - CRTM
  - GOES-R Data assimilation readiness through Visiting scientist
  - NPP ATMS and CrIS data assimilation
  - SSMI/S data assimilation
  - GPS RO data assimilation
  - Etc

# JCSDA FY11 JSDI Selection
(NOAA Internal projects in support of JCSDA)

Proposal Label	Proposal Title	PI	Co-PI
A	JCSDA CRTM Development	Dr. Weng, STAR	Dr. Derber, NCEP
B	Satellite Data Handling & BUFR Tool	Dr. Derber, NCEP	Dr. Weng, STAR
C	Chinese FY-3 MWTS/MWHS Testing in GSI/GFS + SSMIS OSEs	Dr. Weng, STAR	
D	Satellite Wind Assimilation In GSI/GFS	Dr. Derber, NCEP	
E	Cloudy Radiance Assimilation Testing In GSI/GFS	Dr. Weng	
F	OSSE Support for the JCSDA	Dr. Weng	
G	Surface Wind Assimilation Testing/Data Denial experiments	Dr. Jung, Univ of Wisconsin	
H	GPSRO Support for JCSDA	Dr. Cucurull, NCEP	
I	Using Satellite Data to Improve Operational Air Quality Forecasting Capabilities	Dr. Pierce, STAR	Drs. Kondragunta , STAR and Derber, NCEP
J	STAR monitoring of SST analysis quality and EMC support of JCSDA SST analysis (task#1 and 3)	Dr. Ignatov, STAR	Dr. Grumbine, NCEP
K	Quantitative Use of Ocean Color Data in NCEP Operational Modeling	Dr. Bayler, NCEP	Drs. Behringer & Mehra
L	EMC Support for JCSDA Development: Land Data Sets	Dr. Ek, NCEP	
M	Assimilation of Satellite Soil Moisture Data from AMSR-E/ASCAT/SMOS/AMSR2/SMAP	Dr. Zhan, STAR	Dr. Ek, NCEP

- There is a commitment in JCSDA to remain engaged with the external research community to benefit from outside expertise in satellite data assimilation
- Internal JCSDA partners NOT eligible to apply for this external research program
- Priorities revisited for each cycle
- JCSDA acquired IT resources recently (supercomputer), made available to JCSDA external partners to test their science improvement on JCSDA partner systems and codes (O2R)
- The external research program is executed through:
  - NOAA Federally-Funded Opportunity FFO (grants);
  - NASA ROSES announcement (contracts)
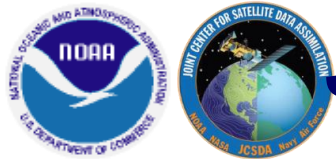
- The review, selection and funding recommendation are performed by the JCSDA executive team, then briefed to the Management Oversight Board

- Projects typically funded for a 2 years period.

- Other programs are approached to coordinate external research funding (success story with NESDIS-GOES-R) which could be extended to testbeds and proving grounds.

- This is the longer-term R2O

- Examples of projects include:
  - Maintenance of high-quality spectroscopy
  - Assimilation of AMVs into NOAA operational models
  - Development of a common, consistent infrared and microwave emissivity database for use as a priori information in the JCSDA
  - Etc

- 42 projects funded so far, since 2004

- FY13 External research (through FFO call) in the final stage.

- FY14 External Research (through NASA Roses 2013) is out.

JCSDA External Research
Selected Projects through the NOAA FY10 FFO

	Proposal		
Number	Title	Institution	PI
1	Radiative Transfer Modeling Support to the JCSDA (Applic. #2176792)	Atmospheric & Environmental Research (AER)	Jean-Luc Moncet, PI Vivianne Payne, Co-PI
22	Techniques for Assimilating Geostationary Lightning Mapper Data & Assessment of the Resulting Impact on Forecasts	NOAA/National Severe Storms Lab.	Don MacGorman, PI Edward Mansell, Co-PI Conrad Ziegler, Co-PI
11	Research in support of Radiance Assimilation of Clouds & Precipitation	University of Wisconsin	Tom Greenwald, PI Ralf Bennartz, Co-PI
3	Data Assimilation of Lighting in WRF 4-D VAR Using Observation Operators (Applic. #2176840)	Florida State Univ.	Henry Fuelberg, PI I. Michael Navon, Co-PI
16	Utility of GOES-R Instruments for Hurricane Data Assimilation & Forecasting	Colorado State University	Milija Zupanski, PI Louis Grasso, Co-PI Dusanka, Zupanski, Co-PI
4	Evaluation & Further Improvement of Land Surface Temperature… (Applic. #2176847)	Univ. of Arizona	Xubin Zeng, PI Michael Barlage, PI Zhou Wang, Co-PI Fei Chen, Co-PI
14	CIMSS Participation in the Utility of GOES-R Instruments for Hurricane Data Assimilation & Forecasting	University of Wisconsin	Jun Li, PI Milija Zupanski, PI Dusanska Zupanski, Co-PI Louis Grasso, Co-PI
10	MODIS & AVHRR-derived Polar Winds Experiments-using the NCEP GDAS/GFS	University of Wisconsin	David Santek, PI James Jung, Co-PI

GOES-R funded

Outline

- ❖ **Monthly Seminar Series**
- ❖ **Summer colloquium in satellite data assimilation (3-year cycle)**
- ❖ **Annual JCSDA workshop on satellite data assimilation**
- ❖ **Joint Workshops with Other Programs and International Partners**
- ❖ **JCSDA Newsletters (quarterly)**
  - ❖ Highlight achievements by JCSDA scientists (internal/external)
  - ❖ Disseminate results and promote collaboration
- ❖ **NOAA is co-sponsoring a data assimilation tenure position at UMD** *(long-term benefit to JCSDA partners: training DA experts)*
- ❖ **Active web site: jcsda.noaa.gov**

Outreach to Other Testbeds, PGs

- **JCSDA Annual Science Workshop**
  - Two or three day meeting taking place each May or June in the DC area
  - Includes JCSDA management and funded investigators
  - Primary purpose is to report progress in JCSDA funded project and in-kind investigations done by partners

- **Joint/International Scientific Workshops**
  - ECMWF-JCSDA Workshop on Clouds and Precipitation , Reading June 2010
  - JCSDA-HFIP Workshop on Satellite Data Assimilation for Hurricane Forecasting
  - Hosting the Fifth *WMO Workshop on the Impact of Various Observing Systems on NWP*, May 2012 in Sedona, AZ, USA

- **Upcoming Joint JCSDA/DTC GSI Tutorial & Workshops**
  - 1st DTC-JCSDA GSI tutorial and science workshop, NCWCP, August 2013

- **JPSS and GOES-R interactions:**
  - Co-leveraging resources (IT, expertise, funding) to perform GOES-R, JPSS –related data assimilation activities (example of S4, FFO, JPSS data gap mitigation efforts, etc)

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1 Overview of JCSDA

2 JCSDA's Mode of Operations

3 Training / Outreach to Other Testbeds, PGs

4 **Highlight of Past JCSDA Accomplishments**

5 JCSDA Current Major Activities

6 JCSDA Support for O2R and R2O

7 Summary

JCSDA Accomplishments

- Community Radiative Transfer Model (CRTM) shared by all partners
- A robust (benchmarked) O2R infrastructure through the JIBB supercomputer open to JCSDA external researchers
- Numerous new satellite data assimilated operationally, e.g.
  - Microwave: AMSU and MHS (radiances, new QC,…), SSMI/S, Windsat, Jason-2,…
  - AIRS and IASI hyperspectral IR radiances,
  - GPSRO sensors (COSMIC, GRAS, GRACE),
  - MODIS (winds and AOD),
- Advanced sensors tested for operational readiness, e.g.
  - ASCAT, OSCAT,
  - MLS,
  - SEVIRI (radiances),
  - Assessment of the impact of FY3 data (MWTS, MWHS)
  - Etc
- Accelerated Readiness to assimilate new sensors (example of NPP/ATMS)
- Improvement to the usage of sensors already assimilated operationally
- Global Observing system Impact Assessment (data denials)

CRTM Mission

• Satellite radiance simulation and assimilation for passive MW,   IR, and Visible sensors of NOAA,NASA,DoD satellites, and others(200 sensors)
• Simulation of clear/cloudy/precipitating scenes, globally

CRTM Applications

• Data assimilation in supporting of weather forecasting
• Physical retrieval algorithm for satellite products
• Stability and accuracy monitoring of satellite observations
• Education and Research: reanalysis, climate studies, air quality forecasting, and a radiative tool for students
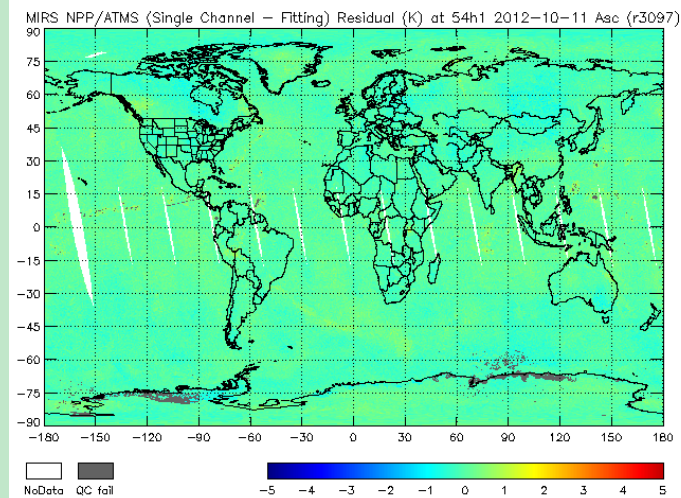
CRTM Future Development

• SBUV for ozone data, JPSS ATMS, CrIS, VIIRS, OMPS, GPM, FY3, Studying feasibility of active sensors including Radar and Lidar space measurements
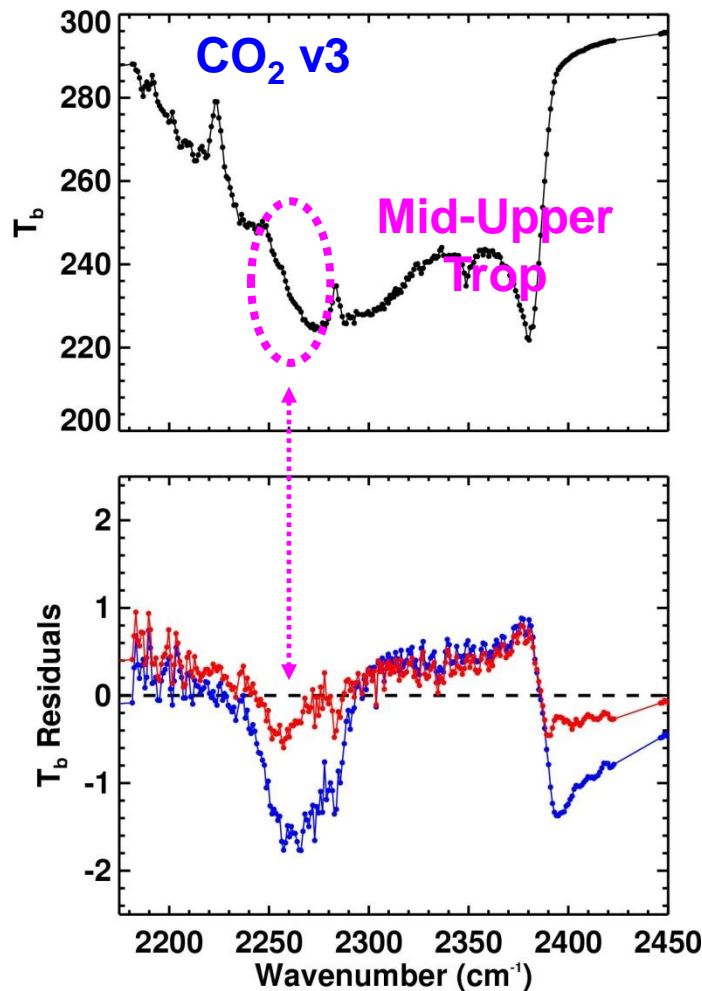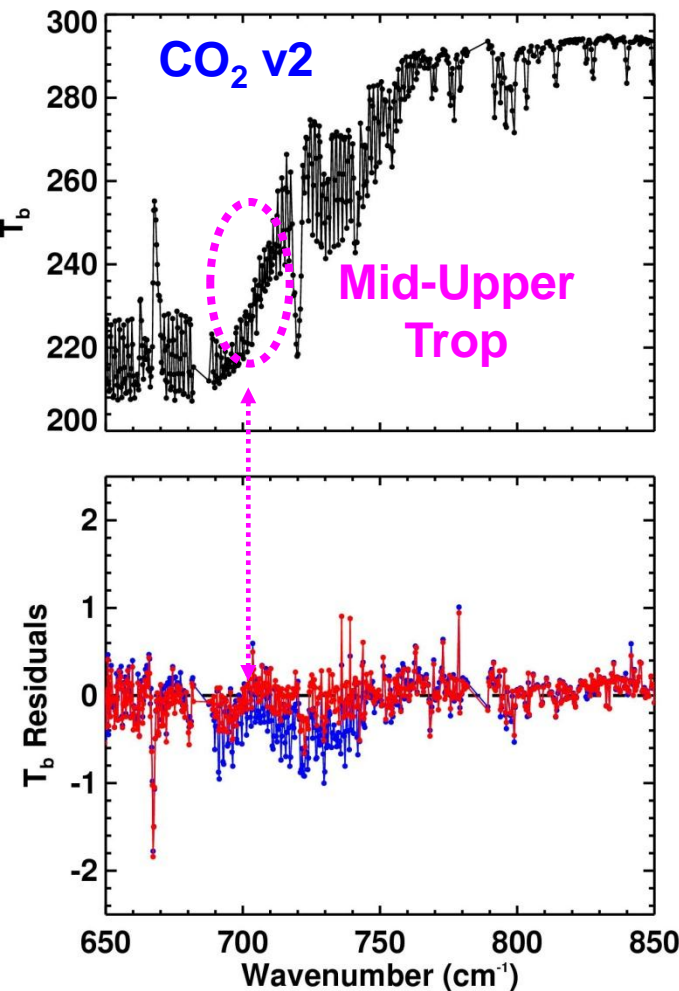
ATMS Ch. 4 (O-B) GDAS
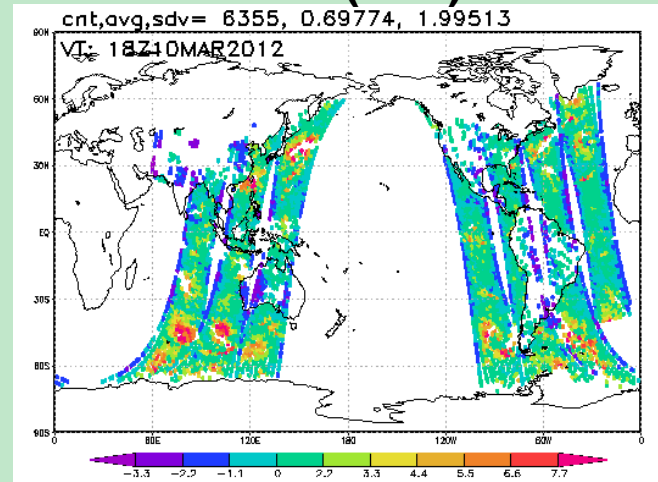
ATMS Ch. 7 1DVAR Residual

Line-By-Line and Spectroscopy

Mean residuals from 36 AIRS ARM TWP cases using Tobin et al. best estimate sonde profiles

Previous version (2006)
- No P/R line cpl
- HITRAN 2000 CO2 parameters

Latest version (2011)
- **P, Q and R line coupling**
- Lamouroux et al. widths and line coupling
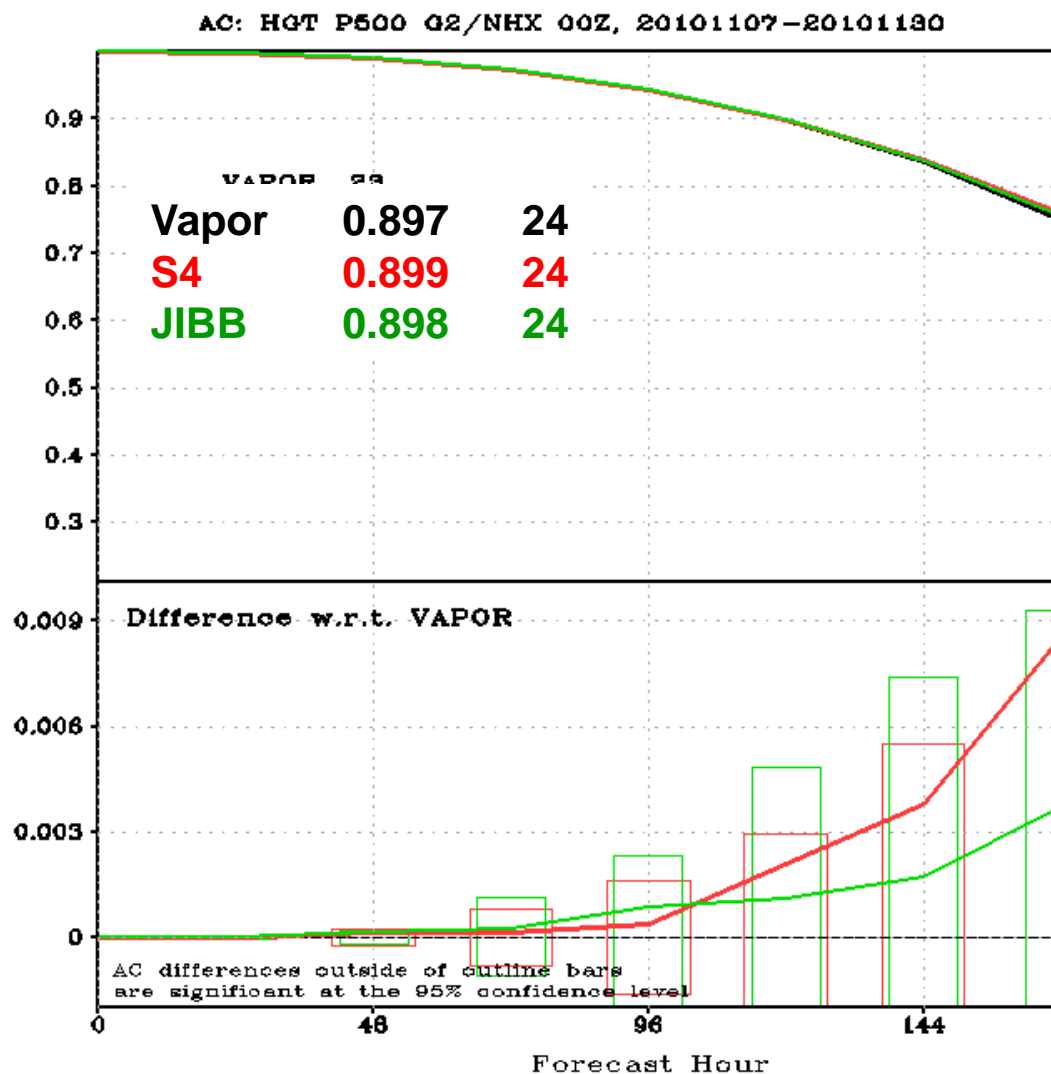- **Tashkun positions, intensities**
- Updated CO2 and H2O continua

Improved agreement (Obs - Calc) and consistency across spectral bands!

(slide courtesy of V. Payne, formerly AER Inc.)

– **NOAA Global Satellite Data Assimilation System (GDAS) was implemented on the JCSDA supercomputer (JIBB) and the NESDIS Supercomputer (S4).**

– **Tests have been undertaken to compare results to those on the JCSDA machine (JIBB) and the NOAA R&D machine Vapor**

– *performances comparison between a series of runs between S4-based, JIBB-based and Vapor-based supercomputers show that correlation performances are consistently similar.*

– *This allows us to declare that the O2R is ready*

AC: HGT P500 G2/NHX 00Z, 20101107-20101130

Vapor	0.897	24
S4	0.899	24
JIBB	0.898	24

Difference w.r.t. VAPOR

AC differences outside of outline bars are significant at the 95% confidence level

Forecast Hour

Plot courtesy of (J. Jung, JCSDA PI)

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- An extensive assessment of the global observing system impact on NOAA forecast system has been undertaken.

- The impact assessment was done wrt satellite data (collectively &individually: microwave AMSU, MHS, GPS, hyperspectral IR, AMVs, etc) as well as conventional data.

- Satellite data as a group, had a very significant impact which surpasses the conventional data impact (by a wide margin), especially in the southern hemisphere.

- **The impacts of individual classes of sensors did not add up to the significant impact above.**

- **Efforts are on-going to assess the impact of combination of sensors, in order to determine the optimal and most significant contributions.**

(1) No Satellite / (2) No Conventional Data

15 Aug – 30 Sep 2010

500 hPa Anomaly Correlations
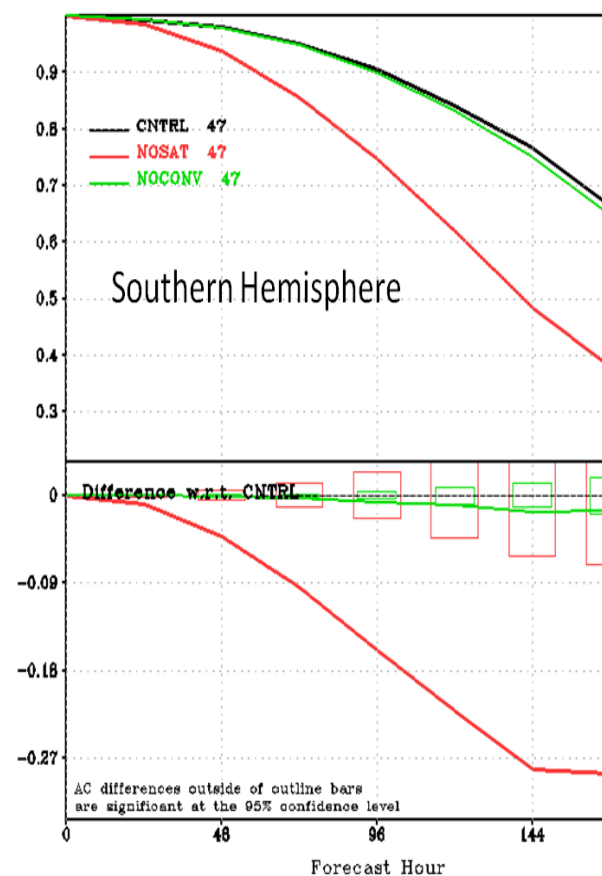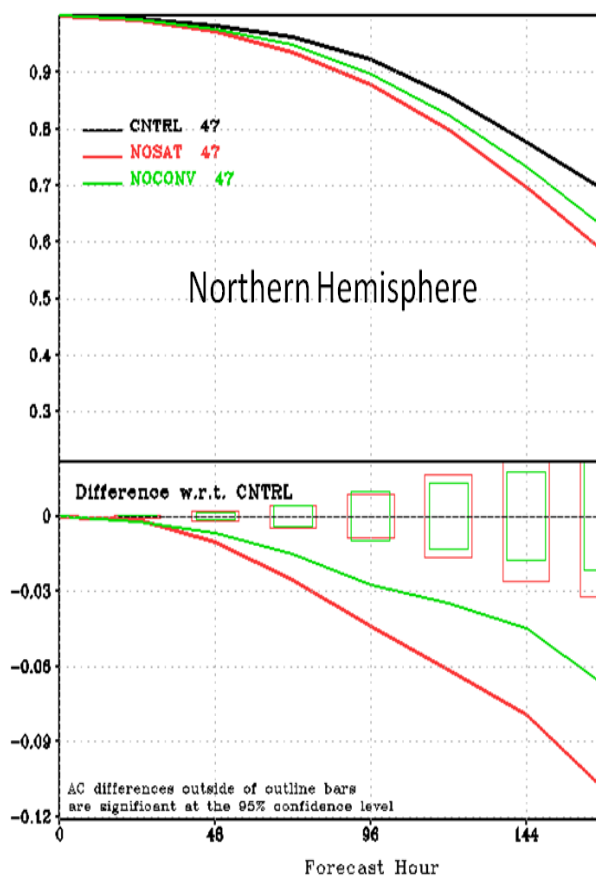
Results from the extensive data denials experiments performed in the JCSDA, aimed at assessing the impact of the global Plots courtesy of J. Jung.
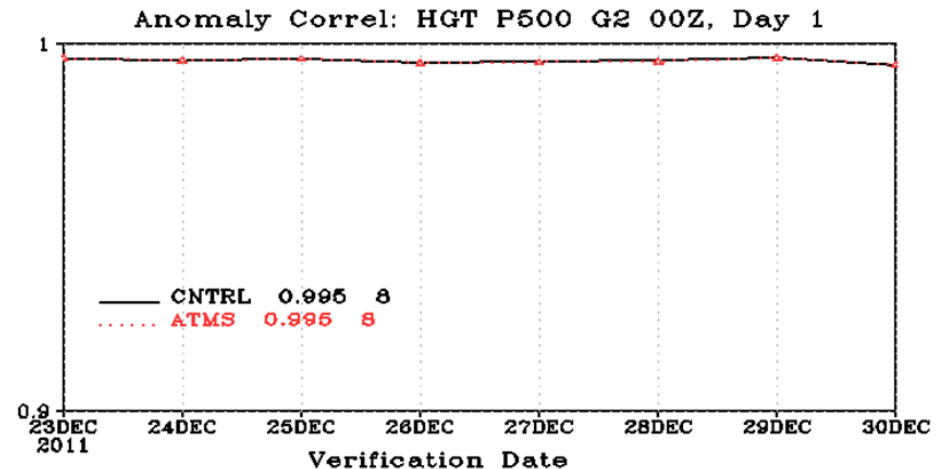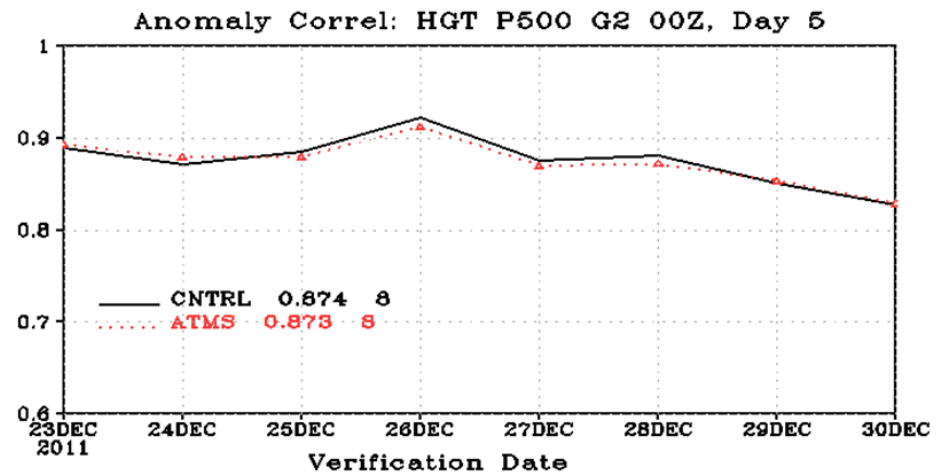
Accelerated R2O for NPP/ATMS

- JCSDA played a critical role in helping NWS accelerate the R2O of NPP/ATMS (one year earlier than originally planned)

- ATMS will be declared operational on May, along with the new version of the hybrid data assimilation system.

- Data Impact assessment of NPP/ATMS was performed on JCSDA infrastructure using new hybrid data assimilation system

- *Results from the ATMS data denials experiments aimed at assessing the impact of the newly launched NPP/ATMS data on the NCEP hybrid assimilation/forecast system show that:*

- *Effect is mostly neutral mainly due to the redundancy of sensors already present*

- *Efforts will be made to assess the impact of ATMS as a replacement sensor (N19, Metop-A)*

500 mb Height AC - Global

Day 1 AC

Anomaly Correl: HGT P500 G2 00Z, Day 1

CNTRL 0.995 8
ATMS 0.995 8

Day 5 AC

Anomaly Correl: HGT P500 G2 00Z, Day 5

CNTRL 0.874 8
ATMS 0.873 8

Plots courtesy of K. Garrett.

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Hurricane Forecast Improvement

- **Hurricane forecast improvement was achieved using the full spatial resolution AIRS temperature. Hurricane Ike (2008) served as test with WRF/3DVAR profiles.**

- **AIRS SFOV temperature soundings improve both the track and intensity forecast for Hurricane Ike (2008) (see plots).**

- **The plan is to do more experiments with water vapor profiles, data thinning, quality control and error covariance.**

- **Storm track bias and sea level pressure SLP differences (with and without assimilating 600 - 800 hPa AIRS high-resolution temperature layers). Improvements are noticeable especially for track bias.**
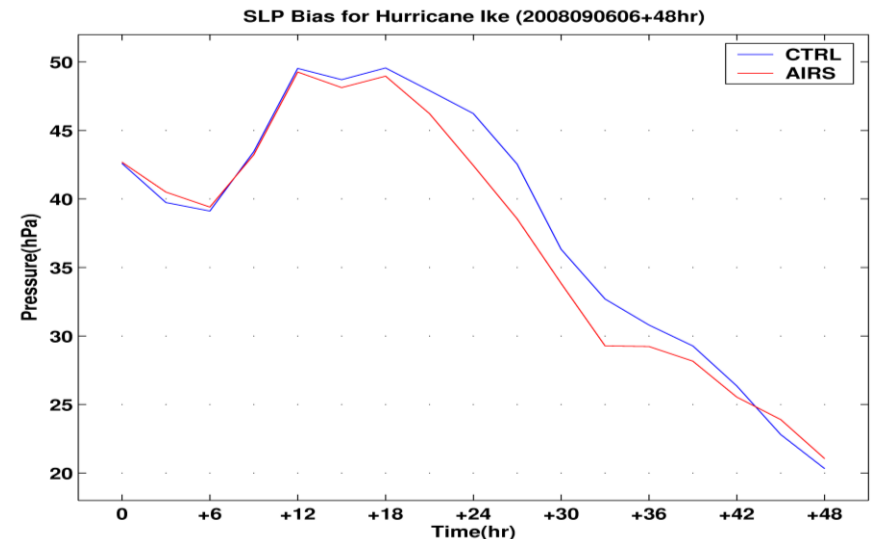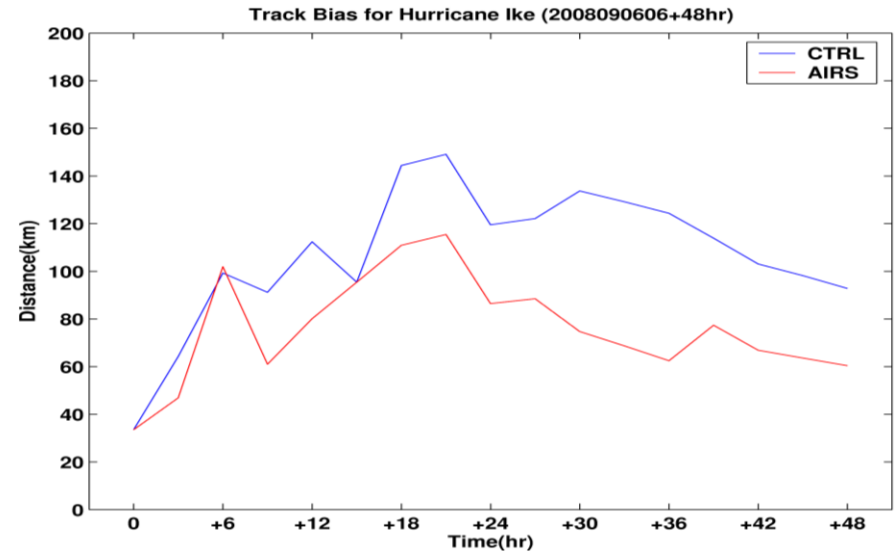

Plots courtesy of Jun Li (CIMMS). FY10 JCSDA FFO project.

GPS RO Assimilation

❖ AC scores (the higher the better) as a function of the forecast day for the 500 mb gph in Southern Hemisphere

❖ 40-day experiments:

- **expx (NO COSMIC)**
- **cnt (old RO assimilation code - with COSMIC)**
- **exp (updated RO assimilation code - with COSMIC)**

AVERAGE FOR 00Z25MAR2008 – 00Z30APR2008
SH 500 mb Height (wave 1–20 AC)
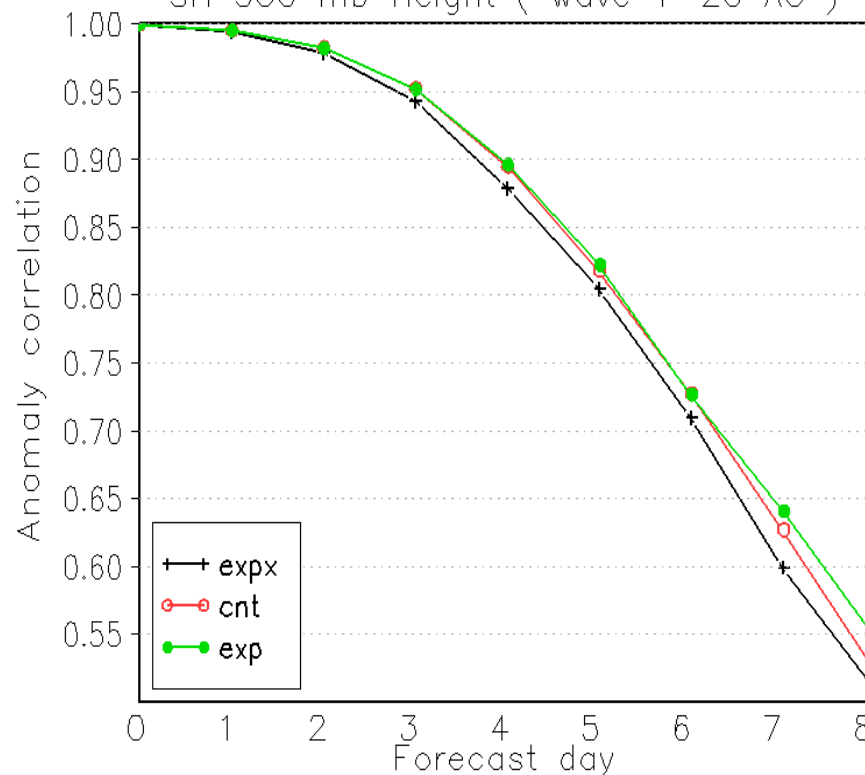
COSMIC provides 8 hours of gain in model forecast skill starting at day 4

Plots courtesy of L. Cucurull. Internal JCSDA project.

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5   **JCSDA Current Major Activities**

6   JCSDA Support for O2R and R2O

7   Summary

- **DATechnique/Tools Readiness & Improvement:**
  - **Global** Data Assimilation (current focus)
  - **Regional** Data Assimilation (emerging priority)
  - Readiness for data assimilation of New Sensors (Metop-B, CrIS, Sat. Winds)
  - On-Going Improvements for already-Assimilated Sensors (sfc-sensitive, QC)
  - Radiative Transfer Modeling (CRTM) & Emissivity Modeling
  - Line-By-Line and Spectroscopy (supported external research)
  - Observing Systems Simulation Experiments (OSSE) & Data Denial Exp. (OSEs)
  - GPS RO Assimilation
  - Cloudy/Rainy Data Assimilation (Infrared and Microwave)
  - Passive and Active Microwave data Assimilation (GCOM-W, GPM, ASCAT, OSCAT)
  - Land and Ocean Data Assimilation
  - Support the JPSS Data Gap mitigation efforts within NOAA (OSEs, etc)
- **Facilitating Research-To-Operations Activities:**
  - Maturing External Research for future Operational Implementation
  - O2R: Establishing an Operational DA Environment for Research
  - Refresh/upgrade of the S4 and/or JIBB systems to face the T1148 resolution of the future NOAA assimilation systems

Within NOAA: Readiness for DA of New Sensors

- **Goal is to have operational users ready to**
  - Assess data from new sensors from day 1
  - Assimilate data from new sensors within one year from launch

- **Current activities include**
  - NPP and JPSS: ATMS, CrIS R2O
  - GOES-R: ABI, GLM
  - AMSR-E/ASCAT/SMOS/AMSR2/SMAP (Soil Moisture)
  - GPS-RO satellites: TerraSar-X (TSX), SAC-C, and C/NOFS

- **Planned activities in the future**
  - Data Assimilation for GPM, Aquarius, AMSR2, and Megha-Tropiques
  - Data Assimilation NASA/SMAP
  - GPS RO payload on: Oceansat-2(ROSA) and PAZ mission
  - Better utilization of SATWINDS data from Space-based Lidar
  - FY-3 microwave sounders (MWTS and MWHS)

- **Activities involve:**
  - Readying proxy data
  - BUFRization of data
  - Modification/testing of satellite data assimilation system and tools
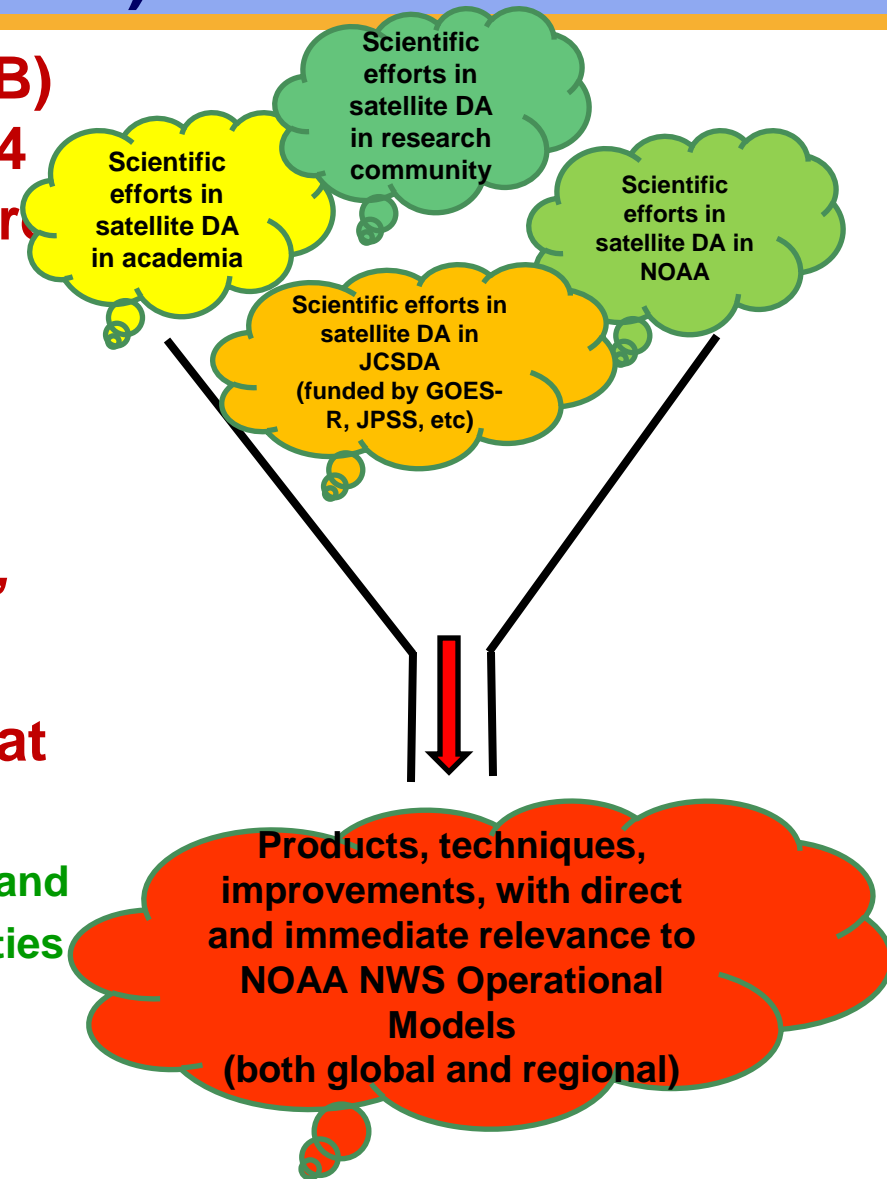 - Impact assessments

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Outline

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JIBB Overarching Objectives (O2R/R2O)

- **The JCSDA Supercomputer (JIBB) and NOAA's Supercomputers (S4 for NESDIS and Zeus for NWS) are a key component in the O2R strategy of the JCSDA for the NOAA partner.**

- **JIBB strategy aims at *'funneling'* the JCSDA data assimilation activities into an environment that is**
  - **Conducive for innovation and research, and**
  - **Relevant to NOAA by *making sure* activities use operational models (which allows immediate benefits)**
  - **Offers an R2O path**

Scientific efforts in satellite DA in research community

Scientific efforts in satellite DA in academia

Scientific efforts in satellite DA in NOAA

Scientific efforts in satellite DA in JCSDA (funded by GOES-R, JPSS, etc)

Products, techniques, improvements, with direct and immediate relevance to NOAA NWS Operational Models (both global and regional)

Example: JIBB Infrastructure

- **The JIBB is not just the supercomputer:**
  - Supercomputer (Hardware, basic software and IT) (*almost* the easiest part!)
  - Scientific Software Integration (the hardest part: keep in synch with operational models)
  - User Support
  - Management of resources
  - Radiative Modeling (CRTM development and proxy data simulation activities)
  - BUFR-formatting tool & satellite data handling ensuring proper feed to NWP
  - **But perhaps more importantly…..(R2O)**
    - A path to operations for those scientific activities/outcomes that show a positive impact on the forecast skill
    - R2O is a subject of a draft agreement between JCSDA and NWS/NCEP that crystallizes the protocols and procedures that need to be followed

Supporting R2O/O2R

Major activities

- Undertake satellite data assimilation experiments at global and/or regional scales and the assessment of their impacts on forecast models skills, using currently flying satellite sensors and allowing scientists to test new science/methodology and

- In support of the activity above, undertake all necessary satellite data simulations, calibration, algorithms development/improvement, radiative transfer modeling and validation, quality control (QC) procedures, etc

- Perform Observing System Simulation Experiments (OSSEs) for new sensors (such as GOES-R and JPSS).

Facilitate Research

- Build and foster infrastructure to support scientific research on parallel to operational systems

- Make available all tools to support major activities - CRTM, GSI, GFS, HWRF, etc (**O2R**)

- Provide guidance for **R2O** path

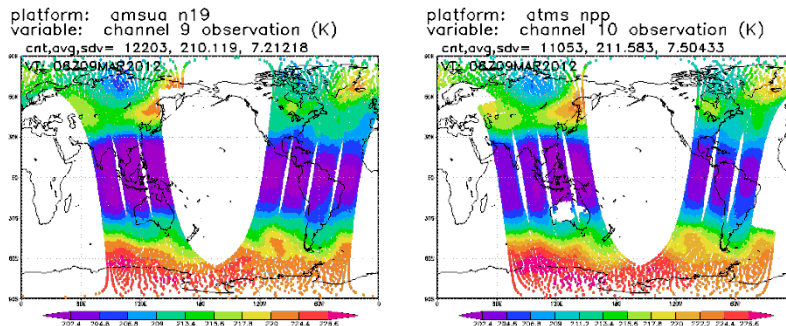- Provide adequate IT resources, CPU power to carry out experiments

Supercomputer for Satellite Simulations and data assimilation Studies (S4), hosted by University of Wisconsin.
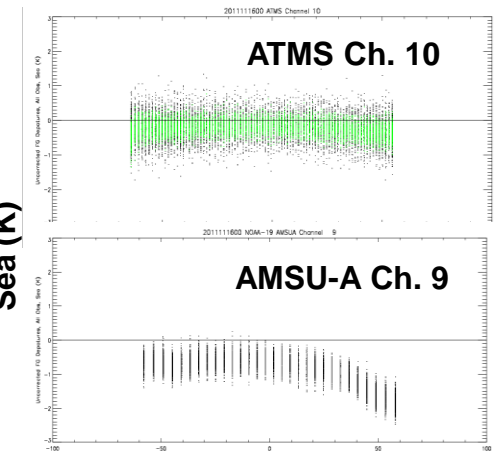
Supporting R2O/O2R

- **NCEP/STAR/JCSDA agreement for *Expedited R2O* of Suomi NPP ATMS in the GSI**
  - Management support for collaboration, resource and responsibilities allocation
- **NCEP/EMC integration of ATMS data in GSI Hybrid**
  - ATMS data processing, quality control, spatial averaging
  - Low-resolution OSE

Observed brightness temperatures for NOAA-19 AMSU-A Ch. 9 (left) and ATMS Ch. 10 (right). Coverage for one GDAS cycle.
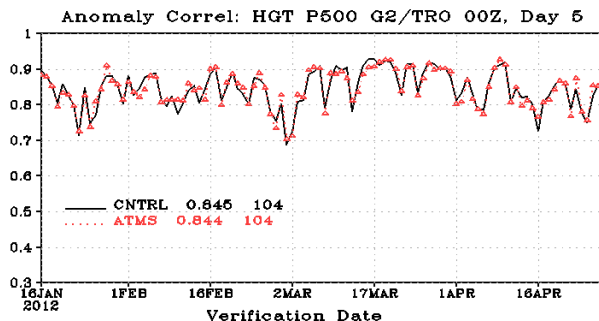

platform: amsua n19
variable: channel 9 observation (K)
cnt,avg,sdv= 12203, 210.119, 7.21218

platform: atms npp
variable: channel 10 observation (K)
cnt,avg,sdv= 11053, 211.583, 7.50433

Anomaly Correl: HGT P500 G2/TRO 00Z, Day 5

CNTRL 0.845 104
ATMS   0.844 104

CONUS Precip Skill Scores, f36

pcntrl
pratms

Difference w.r.t. pcntrl

Threshold (mm/24hr)
Differences outside of the hollow bars are 95%

OSE Results
(TOP) 500 mb Height Anomaly Correlation for 00z forecasts between Jan. 16, 2012 – April 28, 2012 in the Tropics.

(RIGHT) Equitable Threat Score over CONUS 36-60 hr forecast

ATMS Ch. 10

AMSU-A Ch. 9

First Guess Departure Tb - Sea (K)

Satellite Zenith Angle (degrees)

Scan dependent brightness temperature bias (observed-simulated) for ATMS Ch. 10 (top) and NOAA-19 AMSU-A Ch. 9 (bottom)
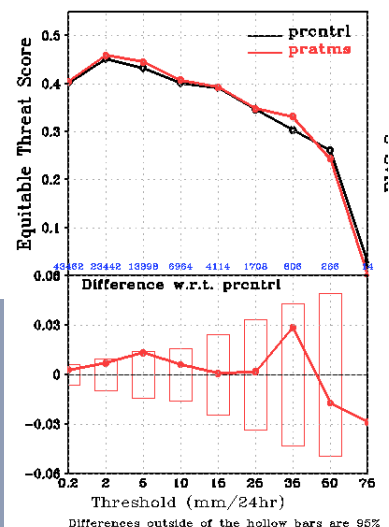
- **JCSDA ATMS OSE**
  - Port GSI Hybrid to S4/JIBB supercomputers (with help from NCEP)
  - High resolution OSE
- **ATMS data impact on forecast is neutral**
  - ATMS data available since 11/8/2011 from NDE (NESDIS/ESPC support)
  - OSEs run from Dec 2011-May 2012
  - ATMS data assimilation capability delivered with GFS/GDAS update to NCO May 22, 2012.

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7 **Summary**

Path Forward & Coordination suggestions

❖ ***Program-level:***

   ❖ **Coordinate/synch calls for proposals?**

   ❖ **Be part of each others' technical review committees (for merit assessment of proposals)**

   ❖ **Establish a program selection committee to deal with programmatic decisions only**

❖ ***Technical Level:***

   ❖ **Exchange visiting scientists ?**

   ❖ **Share resources (codes, tools, IT resources, expertise)**

   ❖ **Information on Who does what (at the technical level not the programmatic level) on the NOAA TBPGC website**

   ❖ **Working groups reach out to experts across testbeds and proving grounds programs**

Summary / Conclusion

- The Joint Center, a US. interagency partnership, is heavily involved in preparing US operational users to benefit from new data as soon as possible after launch

- Scientific Activities of JCSDA are diverse: RT, Ocean, Land, Aerosol, Cloudy Assimilation, etc.

- JCSDA activities have had clear impact on operational activities in all partners
  - Joint systems and code (CRTM, LIS, …)
  - Additional sensors (ATMS, OSCAT, AIRS, MODIS, COSMIC, IASI, SSMI/S,…)
  - Ongoing improvements to assimilation methodology and diagnostics (observation operators, adjoint sensitivity,…)

- The new O2R capability established in JCSDA should consolidate the R2O linkage between NWP community and research community

- Increased collaboration both internally (between partners), nationally and internationally, always welcome and sought
  - VSP and new JCSDA computing are vehicles to strengthen or establish this collaboration